Shorter Proton Bunches

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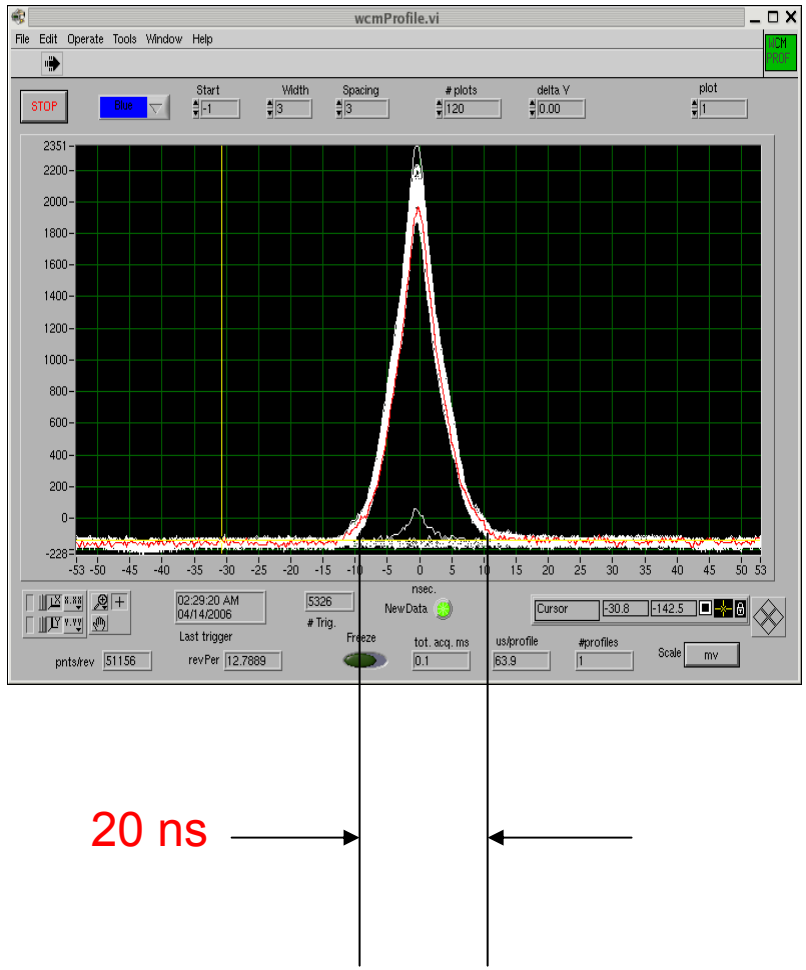
RHIC Retreat

July, 10-13 2006

Danfords On The Sound

Port Jefferson LI



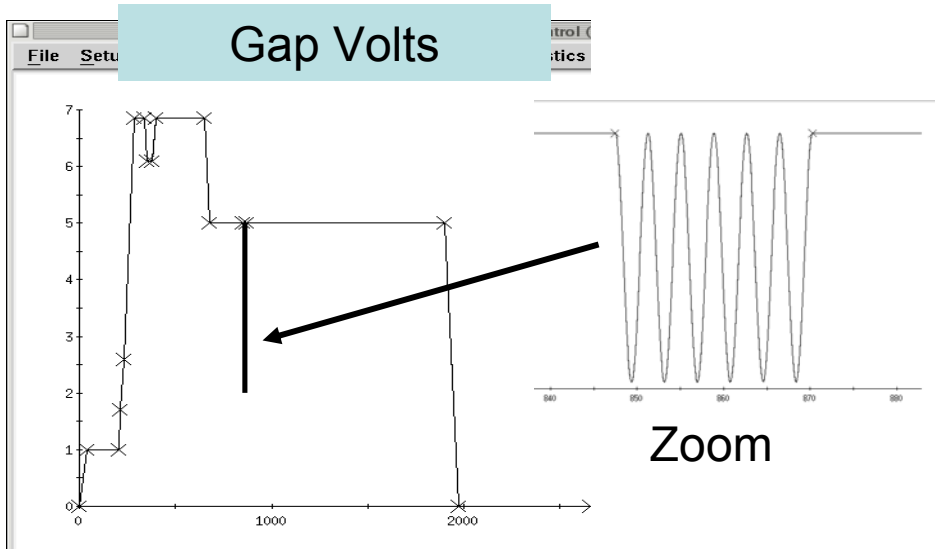
- The bunches are long because the longitudinal emittance is big.
- Or conversely, the longitudinal emittance is big because that makes the bunches long.
- Well, which is it?!
  - Maybe not by design, but in fact it's the latter
  - We learned that shorter bunches bring problems
    - Transverse emittance growth
    - Vacuum problems
    - Instability
- Quad mode pumping was the attempt (ill-fated) to reduce longitudinal emittance and shorten the bunches

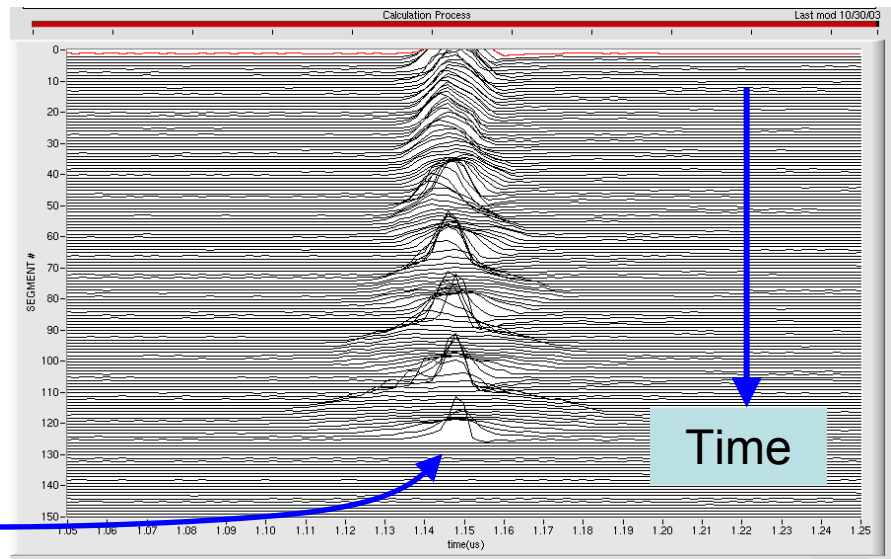
Quad Mode Pumping

- The biggest mechanism of emittance growth is mismatch at RHIC injection
  - Proper matching voltage is very low, 17 kV
  - Beam loading and multipactoring preclude operating the 28 MHz cavities at this low value
- Matching can be achieved, however, by bunch manipulation in the AGS, before transfer
  - This gymnastic is called **Quad Mode Pumping**
  - Interchange energy spread and time (bunch length)

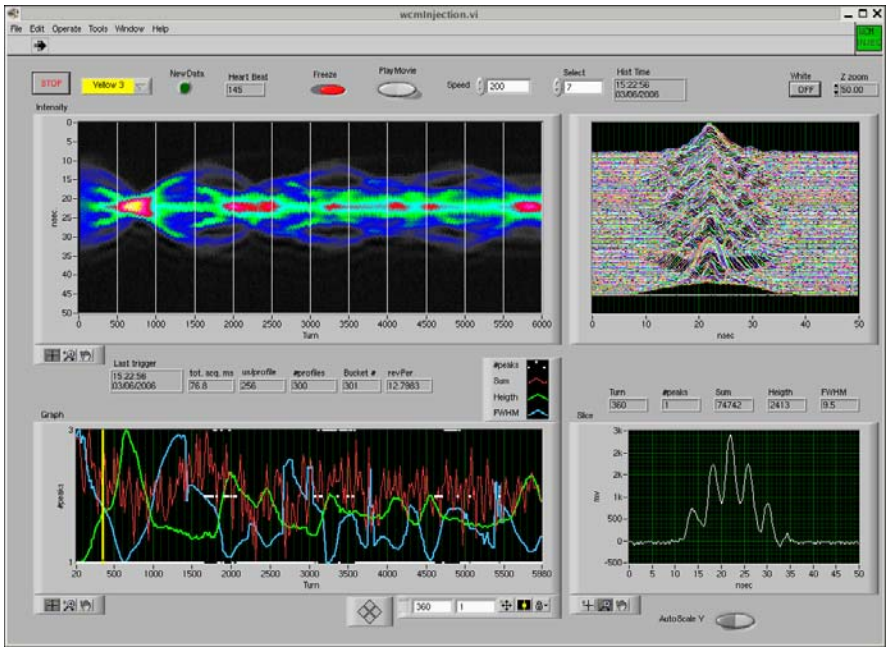
Quad Mode Pumping

- Drive (pump) a quadrupole mode bunch-shape oscillation by modulating the rf voltage at 2 x synchrotron frequency
- Extract when the phase of the oscillation is “short bunch”, large energy spread

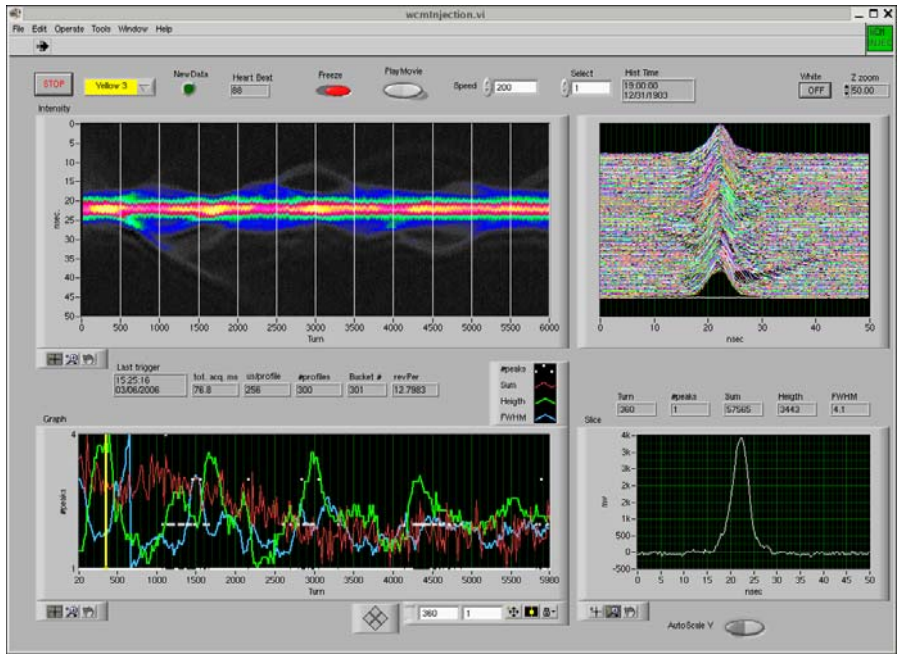




Quad Mode Pumping



Normal injection

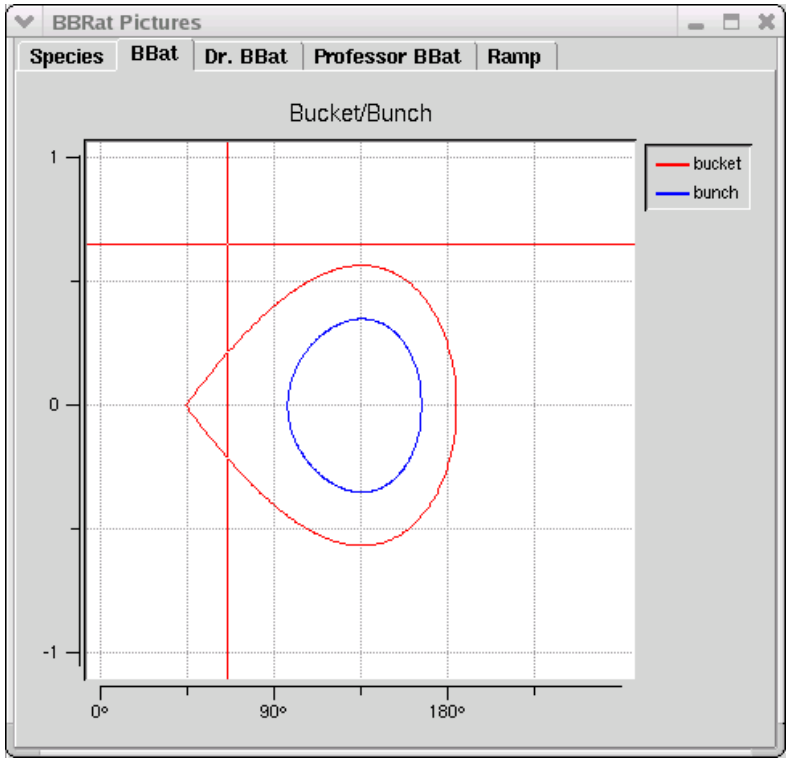


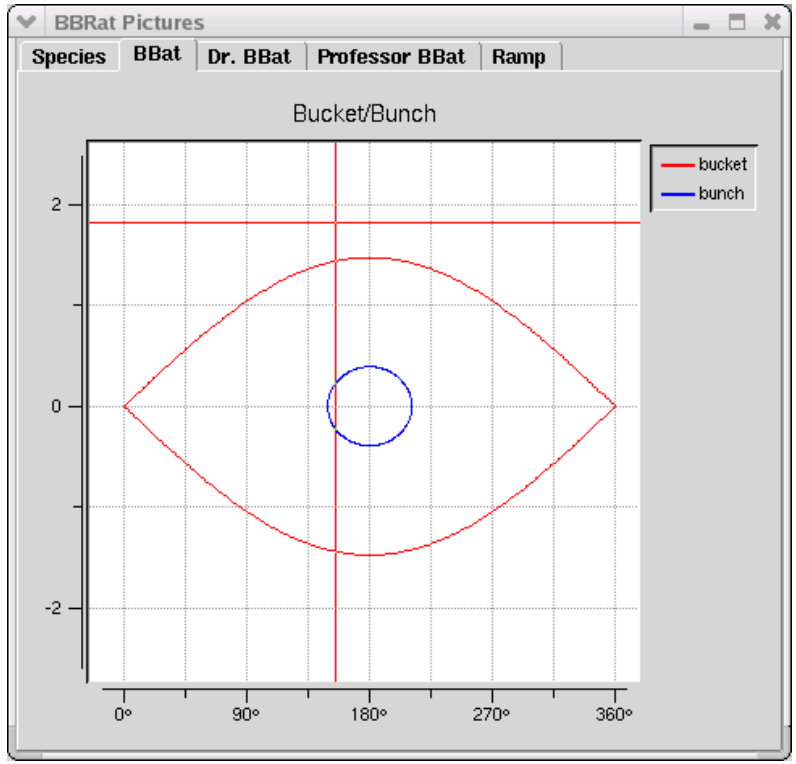
Injection with Quad mode pumping

- It works to match the bunch to the bucket
- Eliminates the emittance blow up
- But that makes short bunches!

How can we have our cake and eat it too?

- Long bunches and low emittance requires very low rf voltage
- Consider a new rf cavity for protons
  - In common pipe (no transition) at n(λ/4) from IP
  - 20 kV is about optimum
  - Very low impedance, ~100Ω (direct feedback)
  - F_{rf}=bunch frequency, 9.3 MHz
- 28 MHz cavities become storage system from protons
  - If $e_{long.}$=0.7 eVs then bunch = 6 ns at 250 GeV
  - No rebucketing, adiabatic turn on





On the ramp

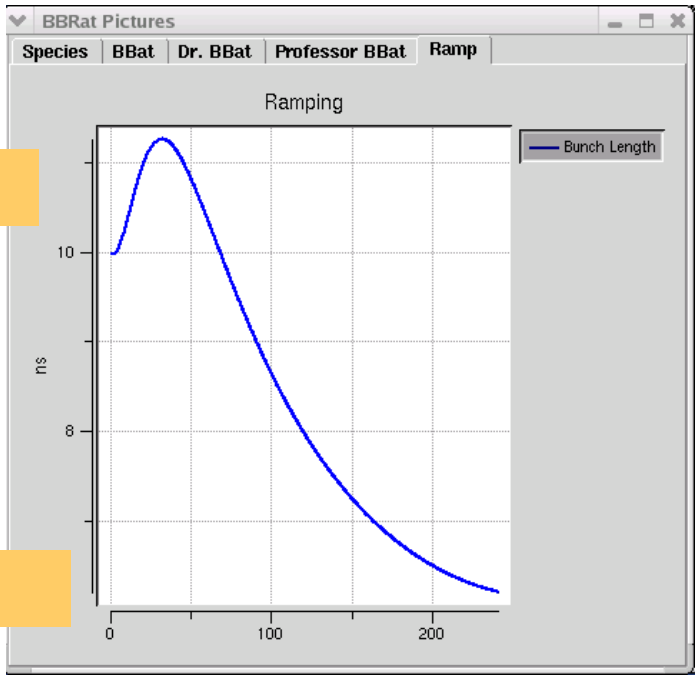
- Max B-dot = 0.015 T/s
- Vrf = 20 kV
- $E_{long.}$=0.66 eVs
- F_{rf} = 9.3 MHz (120 bunches)

At Store

- 250 GeV
- 300 kV, 28 MHz
- Bunch = 6 ns (full width)

Compare the Bunch Lengths

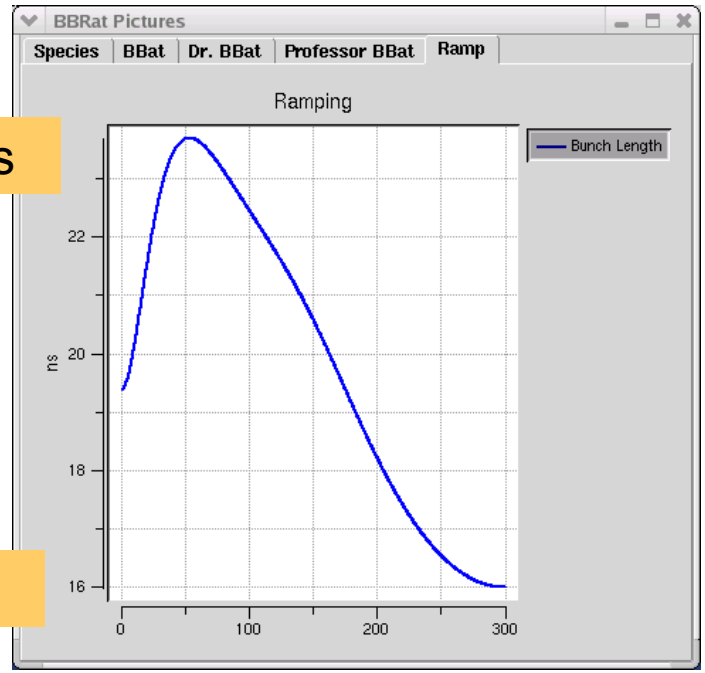
11 ns



6 ns

Ramp with 28 MHz, 0.66 eVs

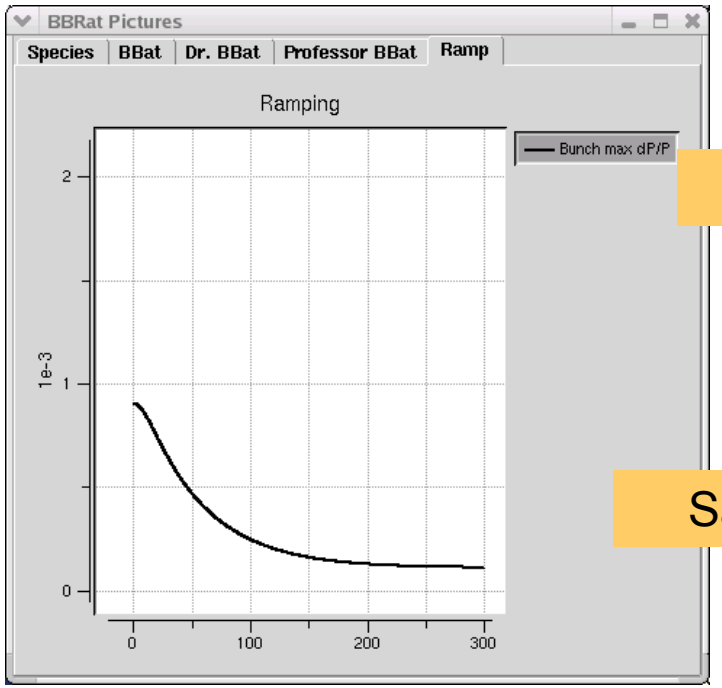
24 ns



16 ns

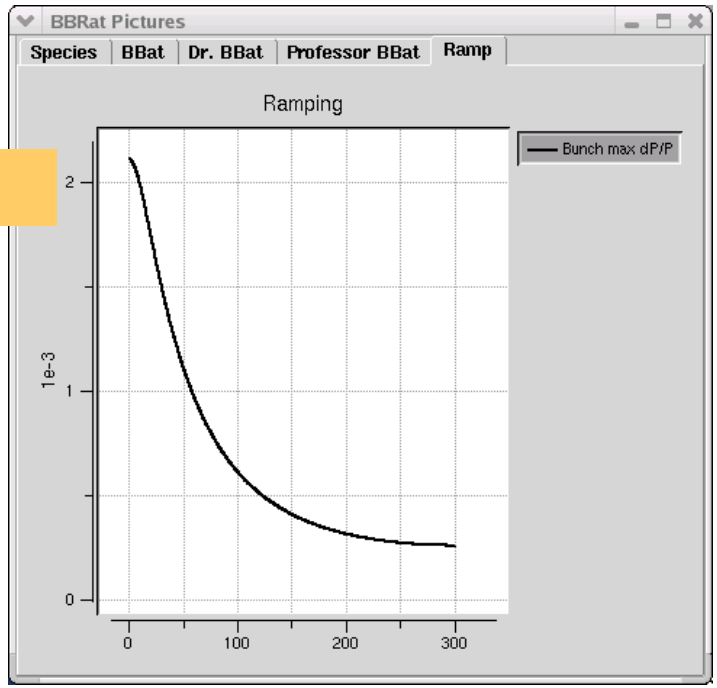
Ramp with 9.3 MHz, 0.66 eVs

Momentum Spread



2×10^{-3}

Same scale

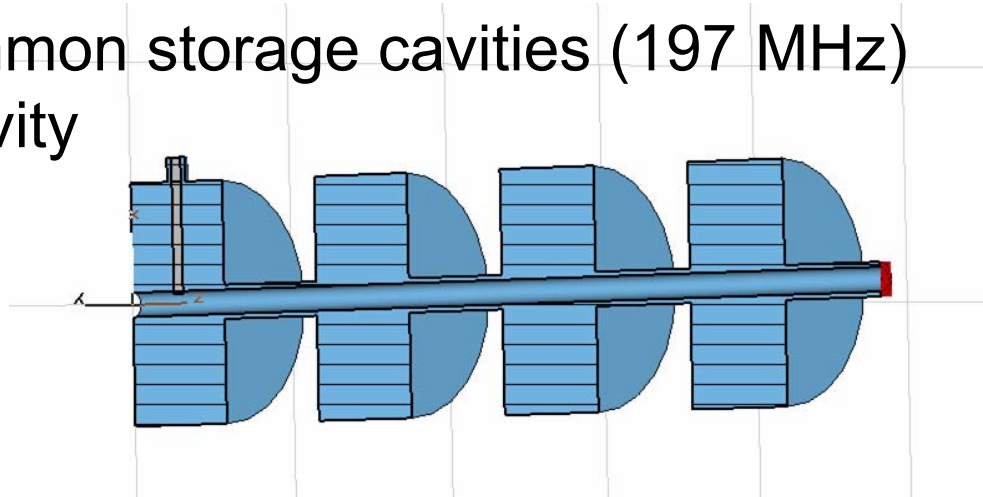


Ramp with 9.3 MHz, 0.66 eVs

Ramp with 28 MHz, 0.66 eVs

A Practical Cavity

- Power supplies from storage system can be used as is
- Cavity options
  1. An “AGS cavity” (ferrite)
  2. A shorted quarter wave line with 1 nF of cap capacitance
  3. Convert the common storage cavities (197 MHz) to one 9 MHz cavity



Summary

- We tried to make the bunches shorter (vertex) by reducing the longitudinal emittance
- The shorter bunches brought new problems
- A win-win solution might be to build a 9 MHz common cavity